A late record for "frost flowers"

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One can but wonder why the ice crystals or "frost flowers" which form on dried plant stems have so long escaped careful laboratory study unless it is because of the unusual conditions of temperature with which they are identified. It is hoped that the following observations may be of interest to research workers and may suggest possible utilization of this phenomenon to advance our knowledge of plant anatomy and physiology.

My first observations of "frost flowers" were made on Nov. 13, 1934. Several plants were found on the western border of the Cumberland University campus around the stems of which large, symmetrical rosettes of ice crystals had formed. The similarity of these ice ribbons to hoar frost attracted my attention. They were formed on an area beginning about 10 cm. above the surface of the ground and extending up the stem about 6 cm. to 8 cm. The rosettes were from 4 cm. to 12 cm. in diameter. In general the largest rosettes were on the stems with the greatest diameter.

The plants on which the crystals occurred had shed all seed and leaves and an exact identification could not be made. All were compositae and, I think, of the genus *Pluchea*. They were under a sparse growth of oak on a gentle slope facing East and slightly protected from westerly and south-westerly winds. At this time the ground was not frozen under the trees and clumps of grass nearby were still green. The bases of the plants were covered by recently fallen leaves.

"Frost flowers" were again observed on this group of plants on Jan. 3, 1935 and I have found no other record of their occurrence so late in the season in this latitude. During the previous night the temperature had dropped rapidly and steadily with only a slow atmospheric drift to the eastward. Hoar frost had formed abundantly in open fields and persisted until after 10:00 o'clock, A.M. Ice about 4 mm. thick had formed on water in shallow depressions. Examination showed the dried stems to be split radially and in some cases to be broken at the level where crystals had formed previously. Below this region, however,

typical "frost flowers" had formed. These were smaller than those observed in November, measuring only 3 cm. to 7 cm. in diameter. All had formed close to the ground; in most cases beginning about 1 cm. above the soil line and extending about 5 cm. up the stem. Many of them had pushed up under or through a mulch of fallen leaves around the base of the stems.

Crystals were observed again on these plants on Jan. 29, 1935. They were small but typical "frost flowers" and were formed beneath the snow! The snow crust was carefully removed from around the plants and a piece of black mulch paper placed behind and beneath the crystals as a contrasting background. The mulch paper was left in place all day and as the sun shone brightly the snow was entirely melted away from the area within 15 cm. of the plants. The crystals melted entirely away from the stems, also. During the night of Jan. 30, typical ice masses 2.5 cm. and 3.5 cm. in diameter formed around the stems. These ice masses were quite symmetrical, whereas those formed under the snow were deformed by pressure against the leaves and snow above them. The ice masses on the stems surrounded by paper were not appreciably larger than those formed on other stems nearby. These ice masses had disappeared by 4:00 P.M. Crystals formed again during the night and, when observed about 9:30 A.M. the following morning, the rosettes were about 1.5cm, in diameter. Atmospheric temperature at the time was about 4° C. and the ice was beginning to melt. At 11:00 o'clock P.M. the night before, the atmospheric temperature (measured about 8 feet above the surface of the ground) was 0° C.

During the interval between my first and second observations Dr. R. M. Harper sent me a reprint—from Torreya 31; 17, Aug., 1931—of his article recording observations of "frost flowers" in Florida. This reprint also contained an article by Mr. H. M. Jennison suggesting an explanation of the mechanics of this phenomenon which he had studied in the vicinity of Knoxville, Tenn. My own observations agree with those of Mr. Jennison so closely that no detailed description of the ice masses need be recorded here. Attempts to cut off stems and photograph the under surface of the ice masses were unsuccessful, the crystals shattering off at the edge of the bark. Immediate examination with a hand lens showed radial plates of ice in the stem. These plates were thicker in the middle than at the edges

of the ribbon and were of clear, transparent ice. The ribbons, themselves, were translucent; a difference which may be due in part to the minute corrugations noted by Mr. Jennison. Small gas bubbles were noticeable in the ice also. Another interesting fact is that where the stems were cut they were still firm and woody. The inner bark was green and appeared to be in a living condition; a circumstance which lends support to the assumption—by Mr. Jennison—that the roots are still active.

It is interesting to note that successive crops of crystals may form on one stem although they retreat toward the base as the stem is split by the ice plates. Their formation under the fallen leaves also confirms the previous assertion that the water is crystallized before it is forced from the stem. It is probable that such formations occur often under cover and are not noticed.

These "frost flowers" suggest a number of interesting problems. If they can be reproduced under controlled laboratory or field conditions, careful study of them may lead to more exact determinations of critical temperatures, root pressures in dormant plants and other physiological and anatomical factors which determine the frost resistance of hardy species. Careful analysis of the gas bubbles enclosed in this ice and of the ice as well may tell us something of the rate of and conditions attending respiration in the roots of dormant plants.

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